Photo: NSF/Hans Boenish

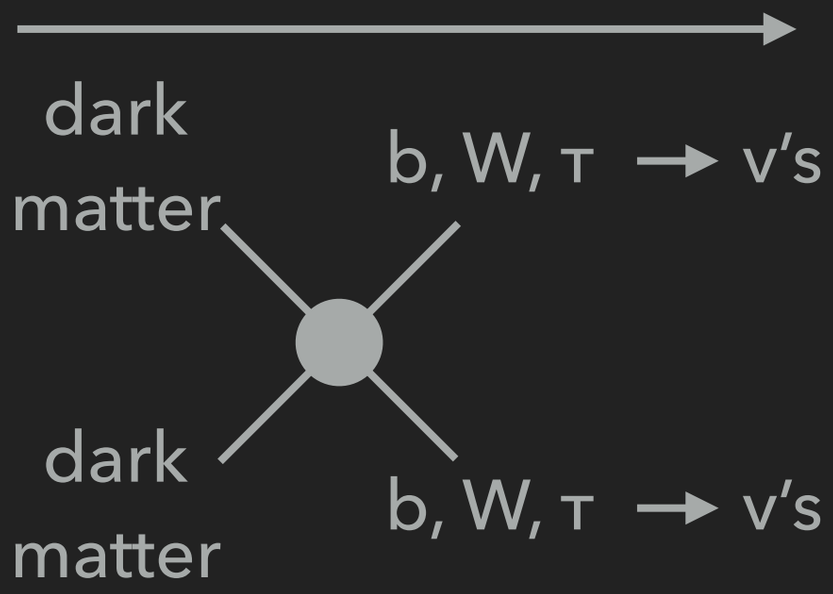
MORTEN MEDICI

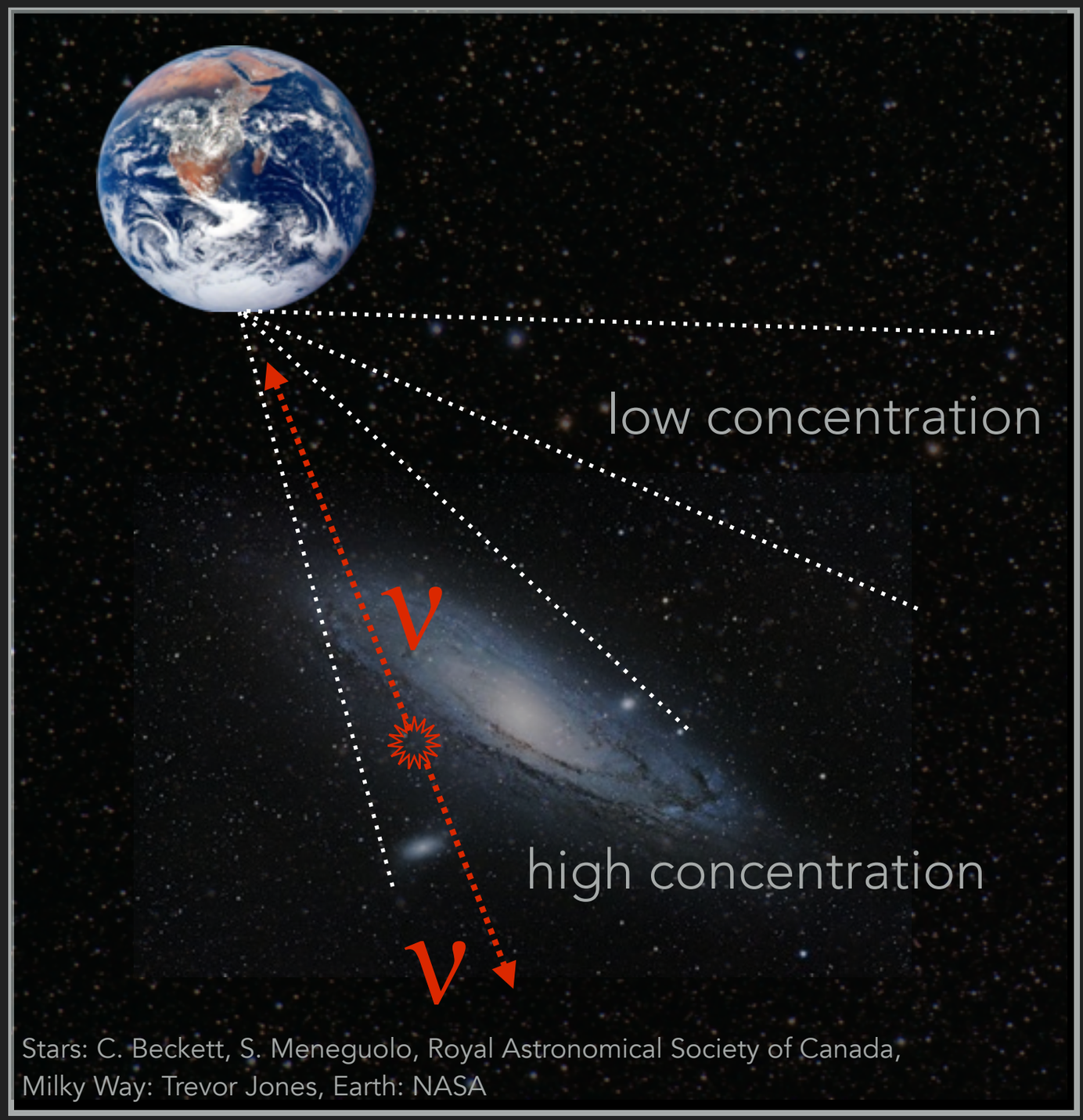
INDIRECT DARK MATTER SEARCHES IN ICECUBE

WIN2017, UC IRVINE

INDIRECT DETECTION WITH NEUTRINOS

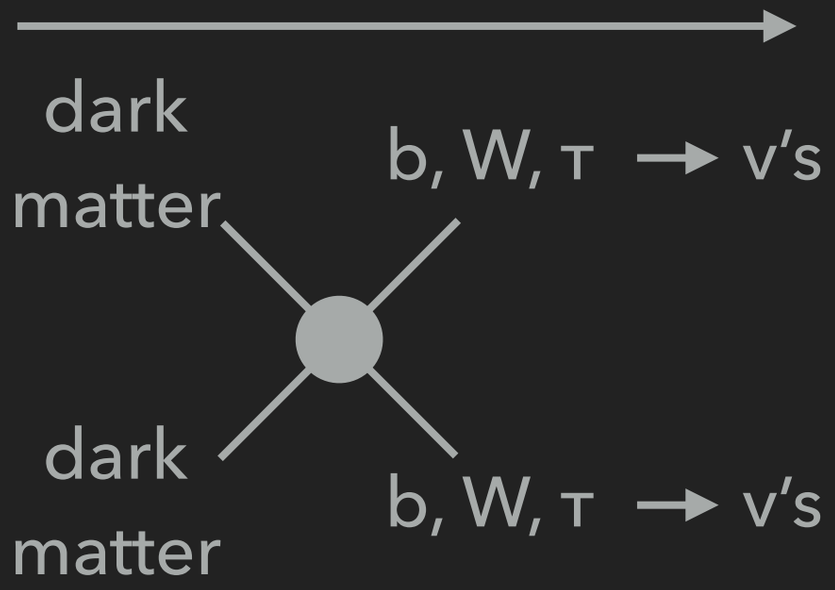
Indirect

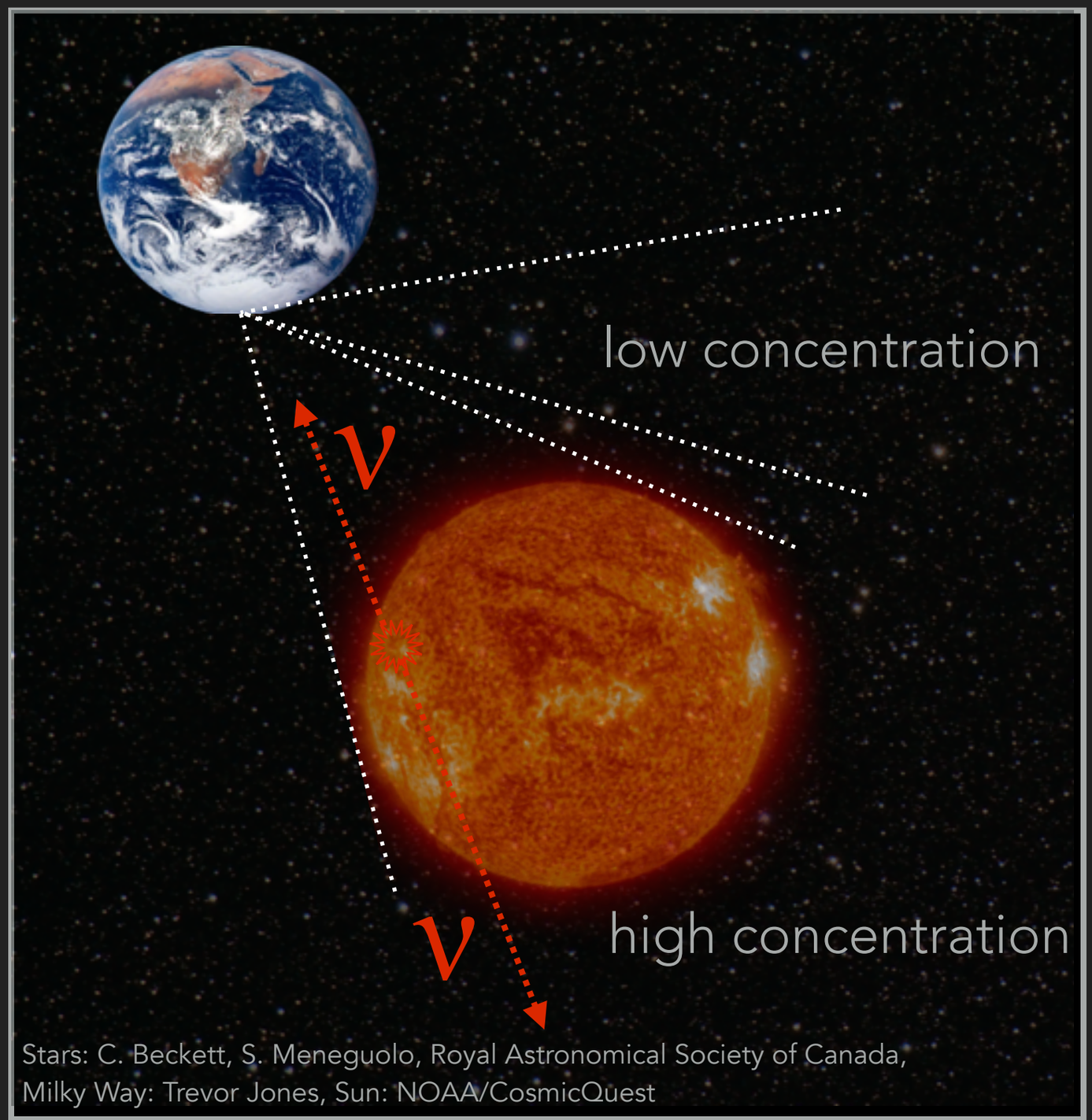




INDIRECT DETECTION WITH NEUTRINOS

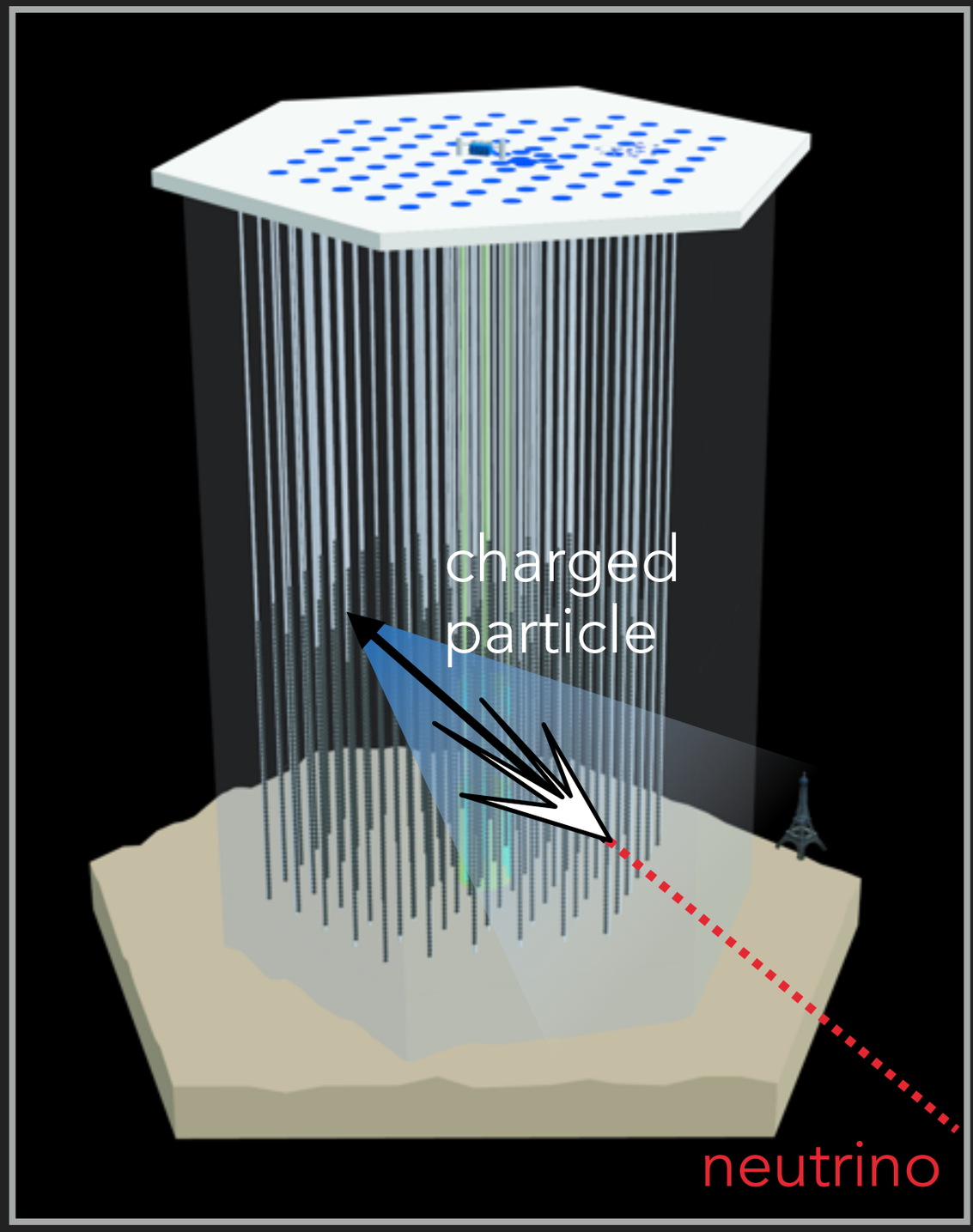
Indirect





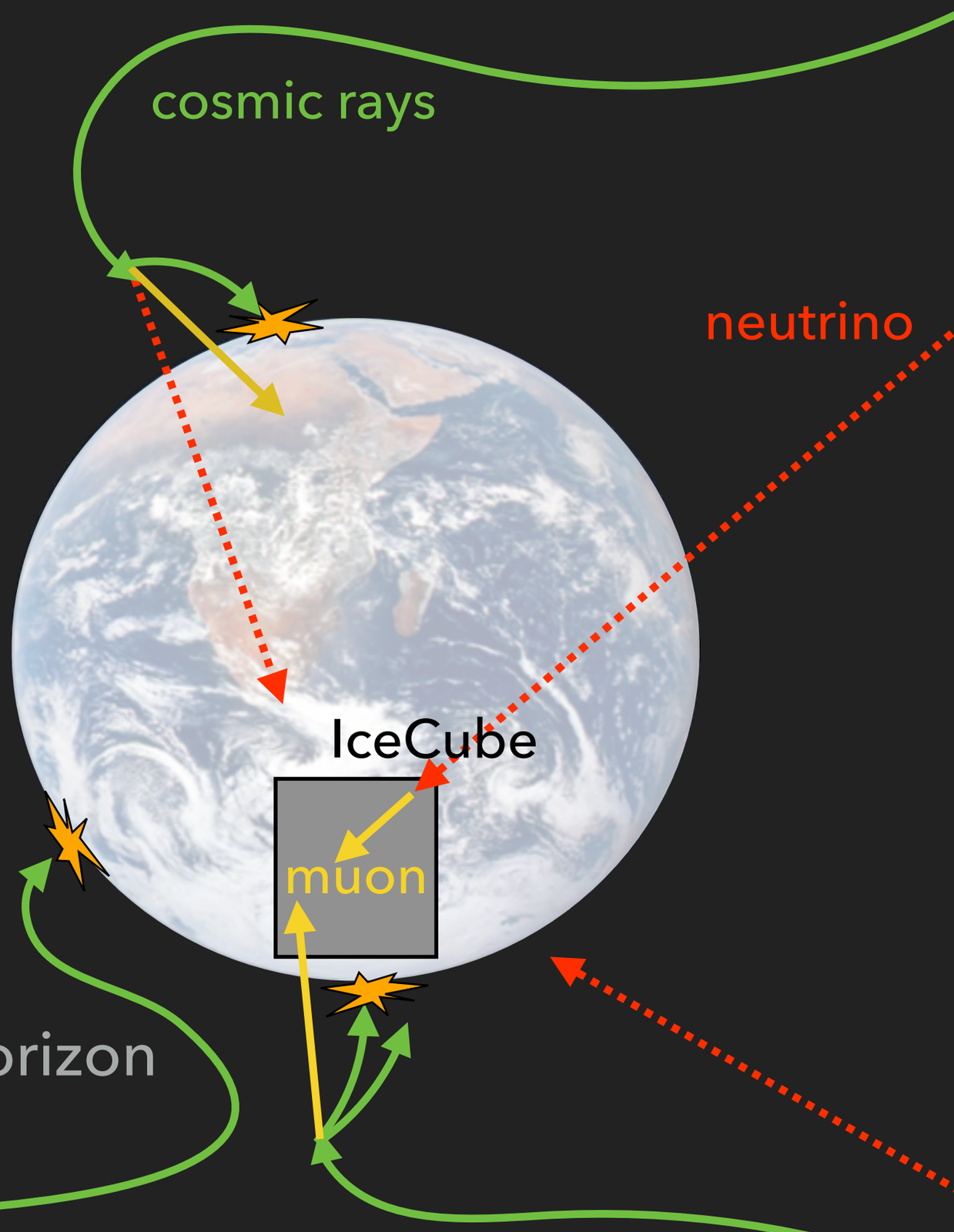
NEUTRINO PHYSICS WITH ICECUBE

- 1 km^3 instrumented ice below the South Pole (finished 2010)
- 5160 light sensors for detecting Cherenkov radiation
- Measuring neutrino-initiated events
- Energies down to 10s GeV
- Stable operation and reliable hardware (> 99% livetime)



SIGNAL AND BACKGROUND

- **Background at trigger level**
  - Atm. muons: 10^{11}/year
  - Atm. neutrinos: 10^{5}/year
- **Dark matter searches**
  - Sun: +/- 23° above horizon
  - Galactic center: 29° above horizon



ICECUBE EVENTS

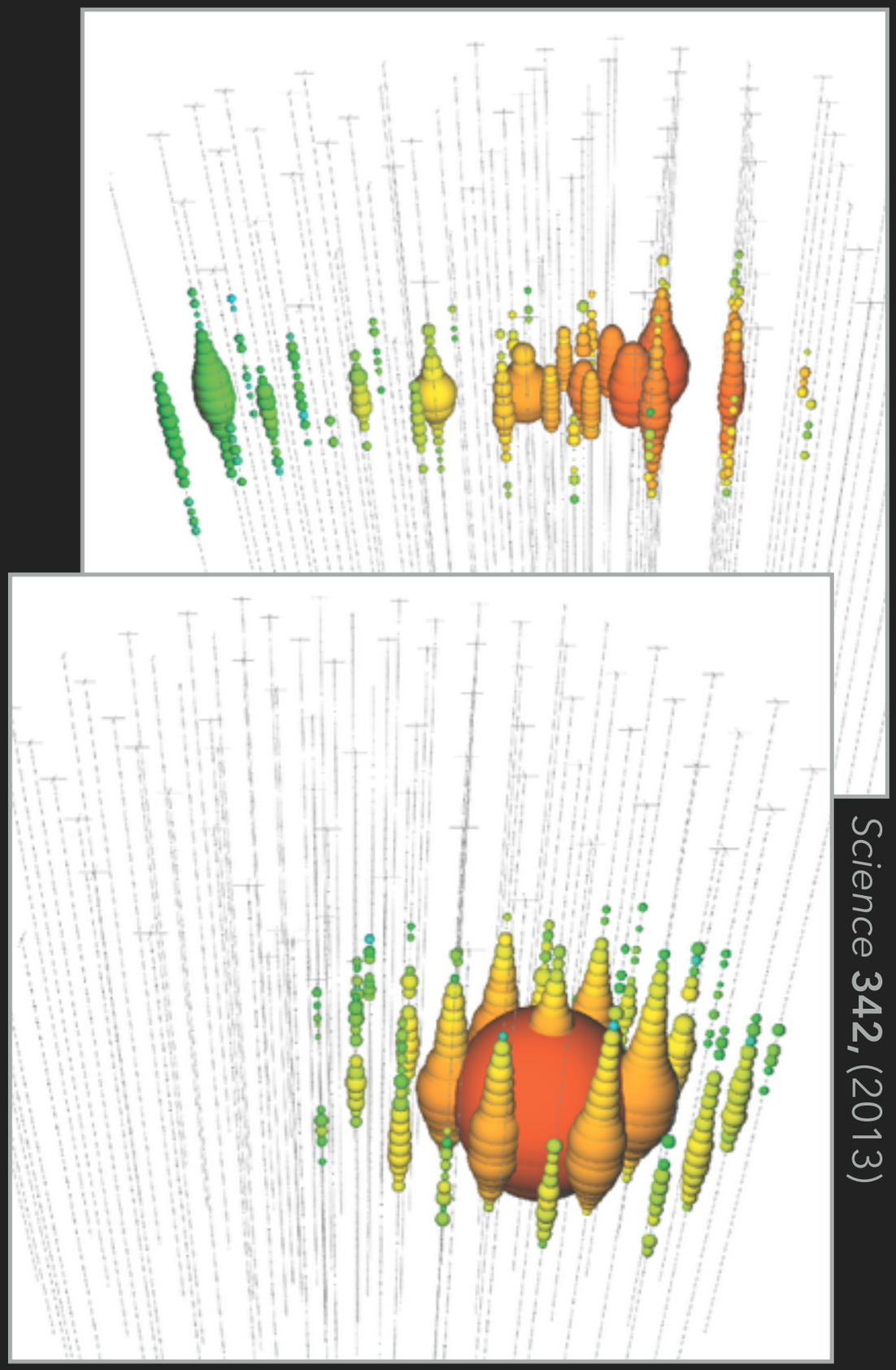
- Two topologies:
  - **Tracks** (best pointing)
  - **Cascades** (contain all energy)

- Reconstruct neutrino:

  Charge, time, geometry

  ↓

  Direction, energy, position



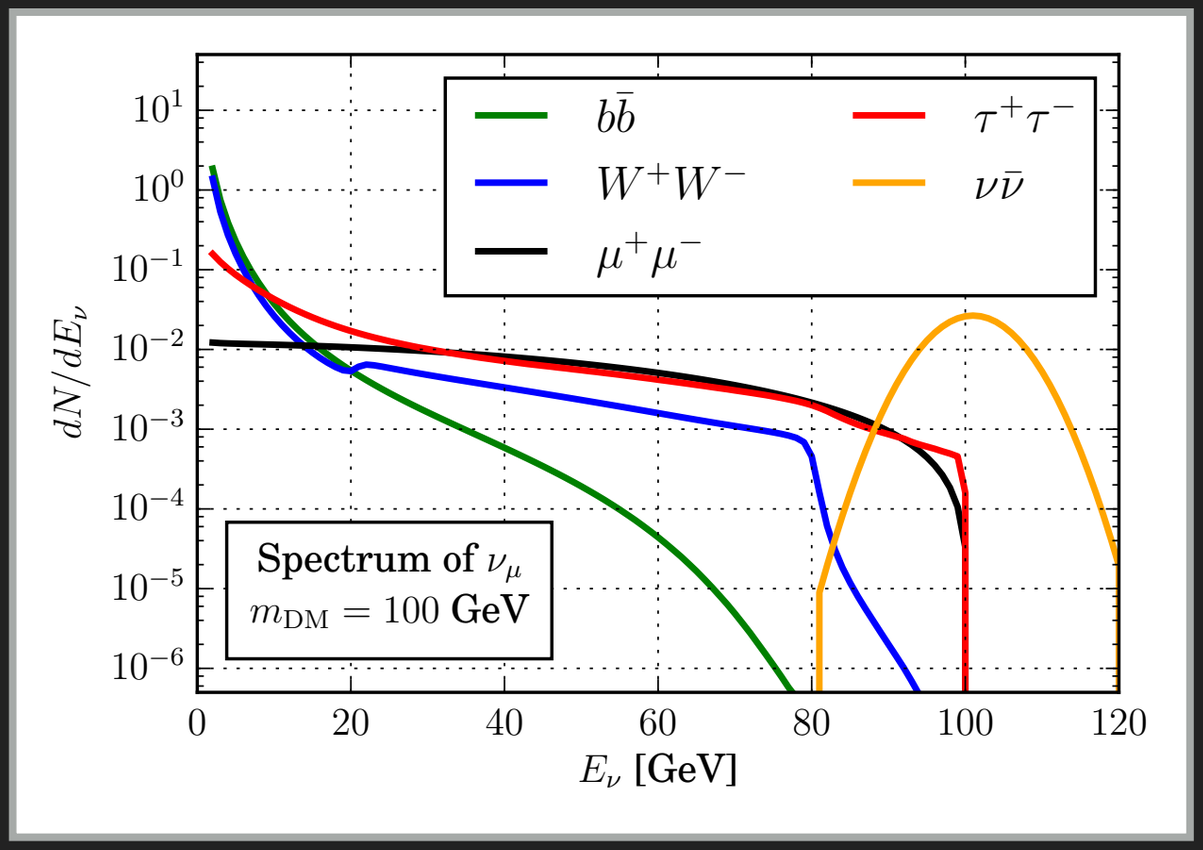
Science **342,** (2013)

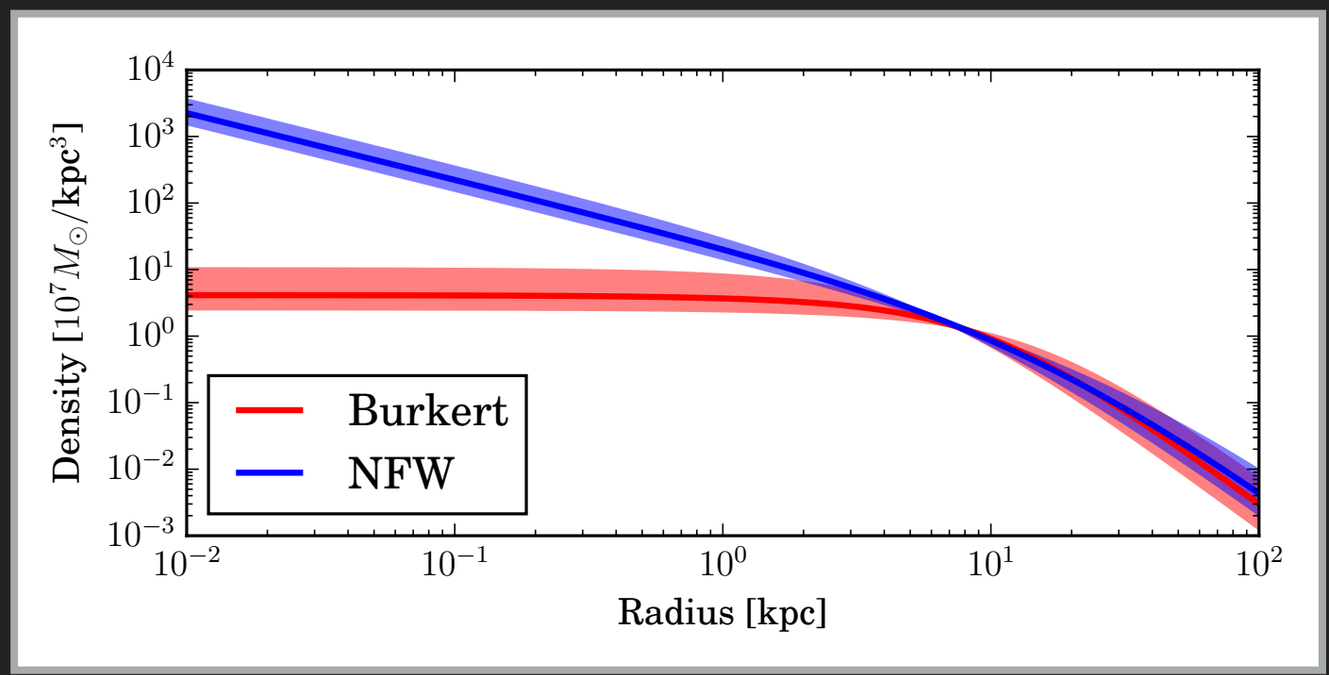
GALACTIC HALO

TARGETED SIGNAL FROM GALACTIC HALO

- Spectrum model dependent
- Signal sensitive to assumed halo profile

$$\Phi = \frac{\langle \sigma_A v \rangle}{4\pi \cdot 2m_{\mathrm{DM}}^2} \frac{dN}{dE}(E_\nu) \int_{\mathrm{los}} \rho_{\mathrm{halo}}^2(\Psi)$$





ANALYSIS TECHNIQUE

- Likelihood approach with a mixture of:
  - **Signal**: Modelled from simulated neutrino events weighted to correspond to dark matter annihilation
  - **Background**: Estimated from exp. data
- Signal contamination in background is subtracted
- Same approach used across all presented galactic halo analyses

LATEST UPDATE ON ANALYSES

- Covering dark matter masses from **10 GeV to 300 TeV**
- Exploiting three different event selections, each optimised for a specific class of events

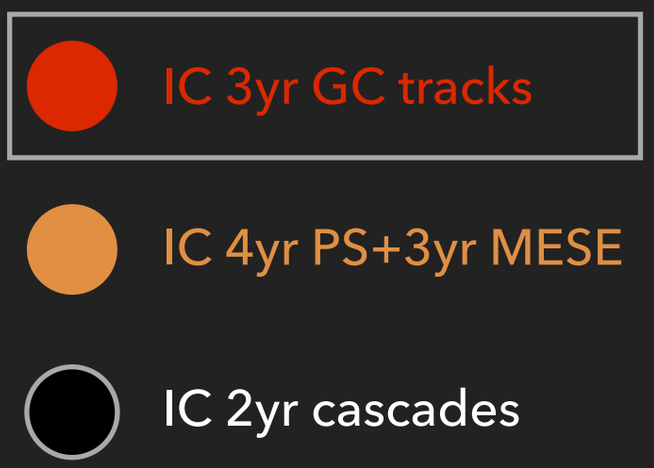
IC 3yr GC tracks

IC 4yr PS+3yr MESE

IC 2yr cascades

LOW ENERGY ANALYSIS

- Dark matter masses between **10-1000 GeV**
- Using the finished IceCube with 86 strings
- Exploiting good pointing resolution of the muon **tracks**
- Implementation of new **event reconstruction** important below neutrinos energies of 100s of GeV
- 3 years of data: 1007 days of livetime
- Results submitted and public **[arXiv:1705.08103]**



HIGH ENERGY TRACK ANALYSIS

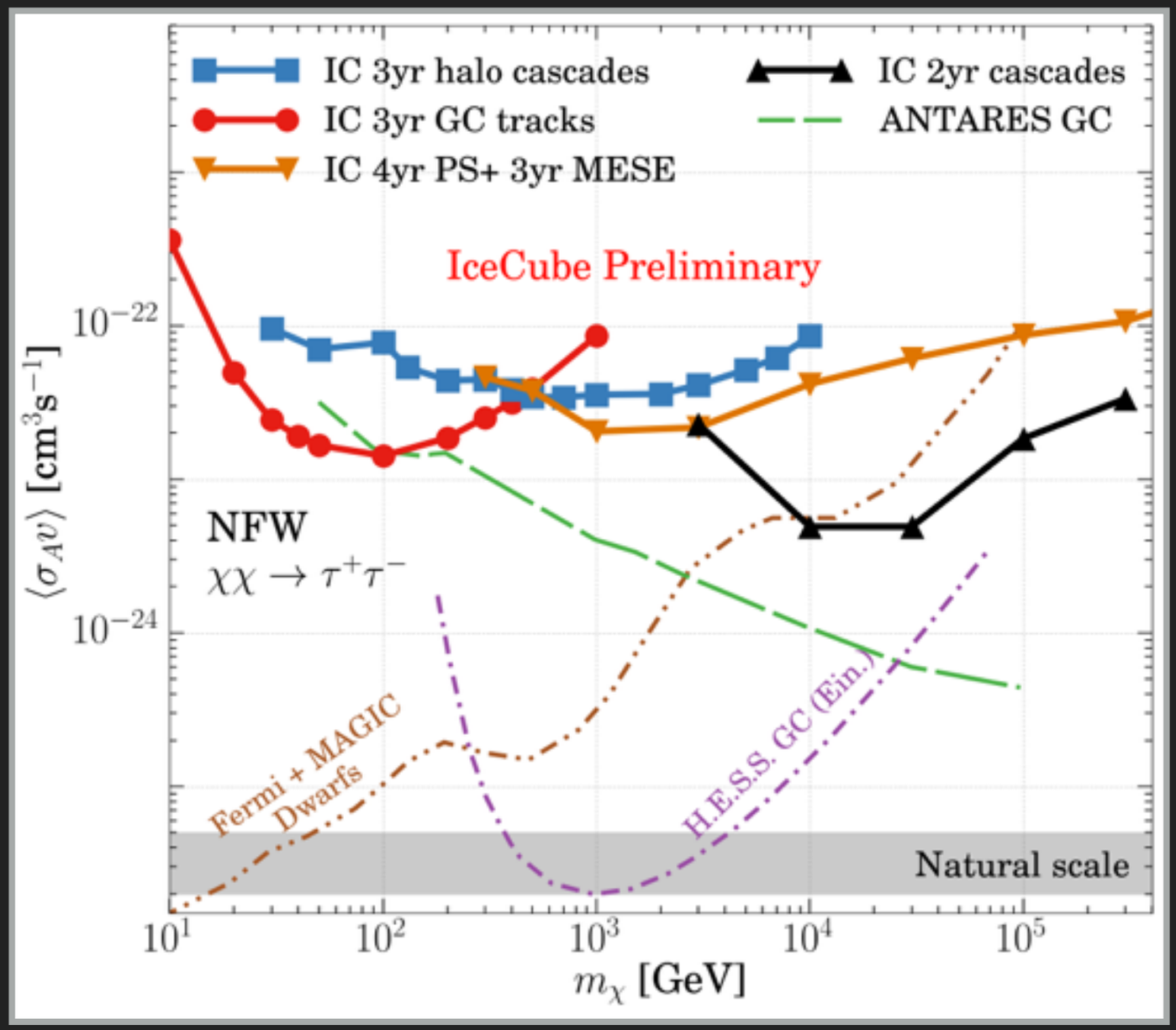
- Dark matter masses between **0.3-1000 TeV**
- Using **tracks** from IceCube dataset designed for point source searches (PS)
- Focus on galactic halo makes it **less effected** by the dark matter halo profile assumptions
- Includes an IceCube dataset dedicated to the southern hemisphere (MESE)
- Inclusion of **energy** in likelihood analysis provides extra sensitivity above 10s TeV

HIGH ENERGY CASCADE ANALYSIS

- Dark matter masses between **3-300 TeV**
- Exploiting the good energy resolution from **contained cascades**
- Inclusion of **energy** provides extra sensitivity above 10s TeV
- Using an IceCube dataset designed for an unfolding analysis of the neutrino spectrum
- Implementing a progressively larger veto for lower energy events

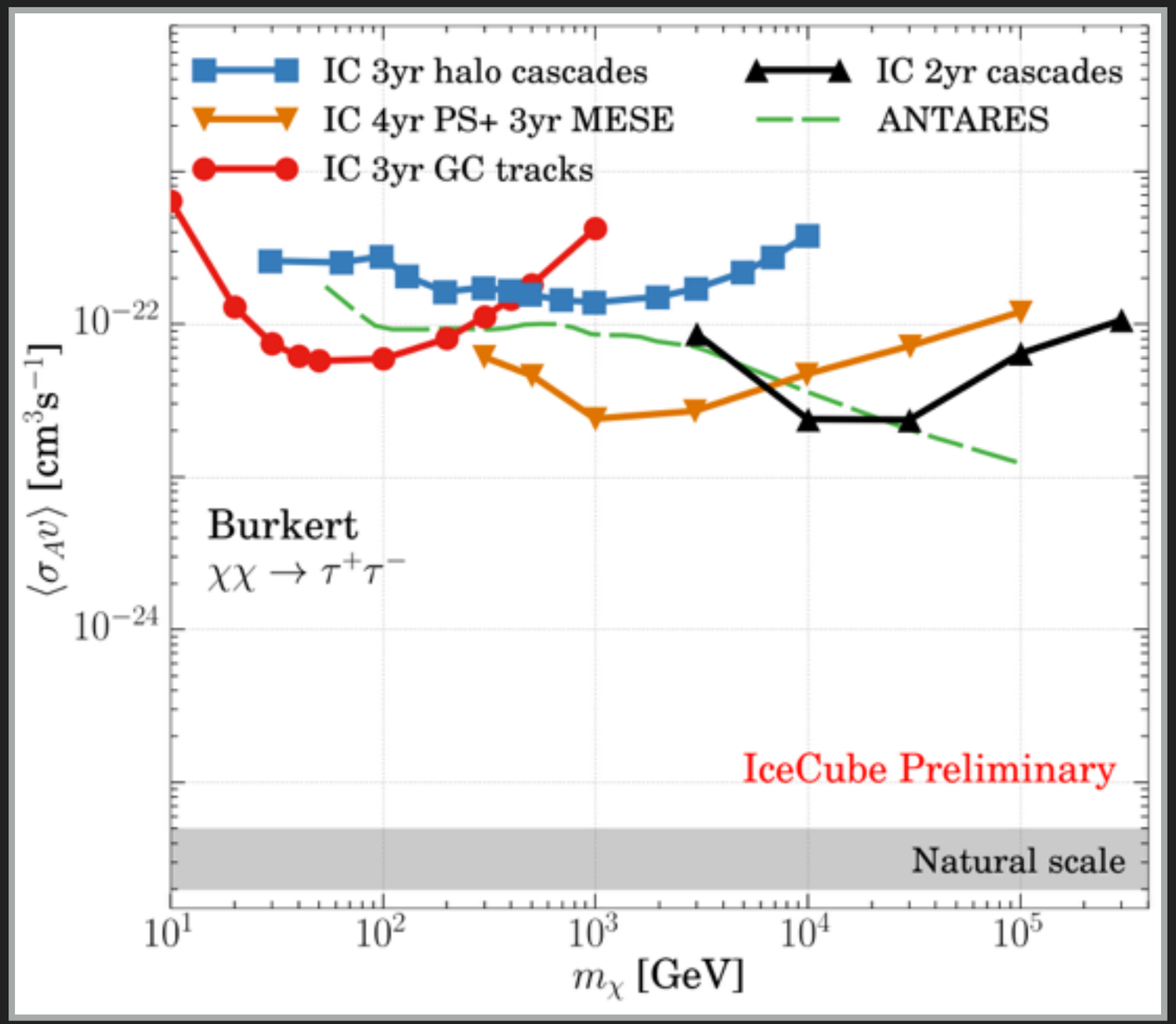
GENERAL SUMMARY: GALACTIC HALO WIMPS

- No excess above the expected background was seen



GENERAL SUMMARY: GALACTIC HALO WIMPS

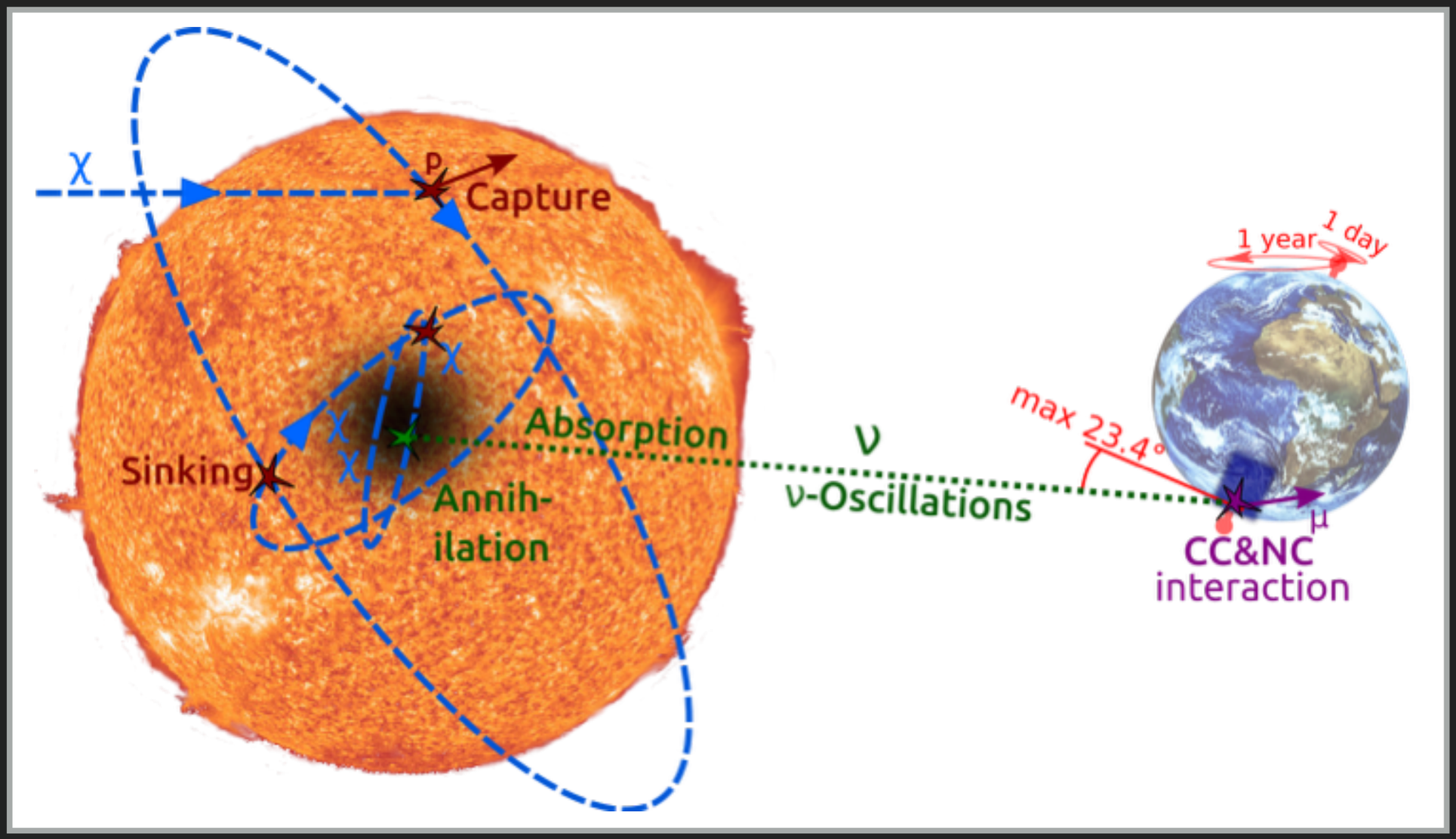
- Assuming Burkert dark matter halo profile



SOLAR SEARCH

TARGETED SIGNAL FROM THE SUN

- Accumulation of WIMP in the sun, assumed to be in equilibrium with the annihilation rate

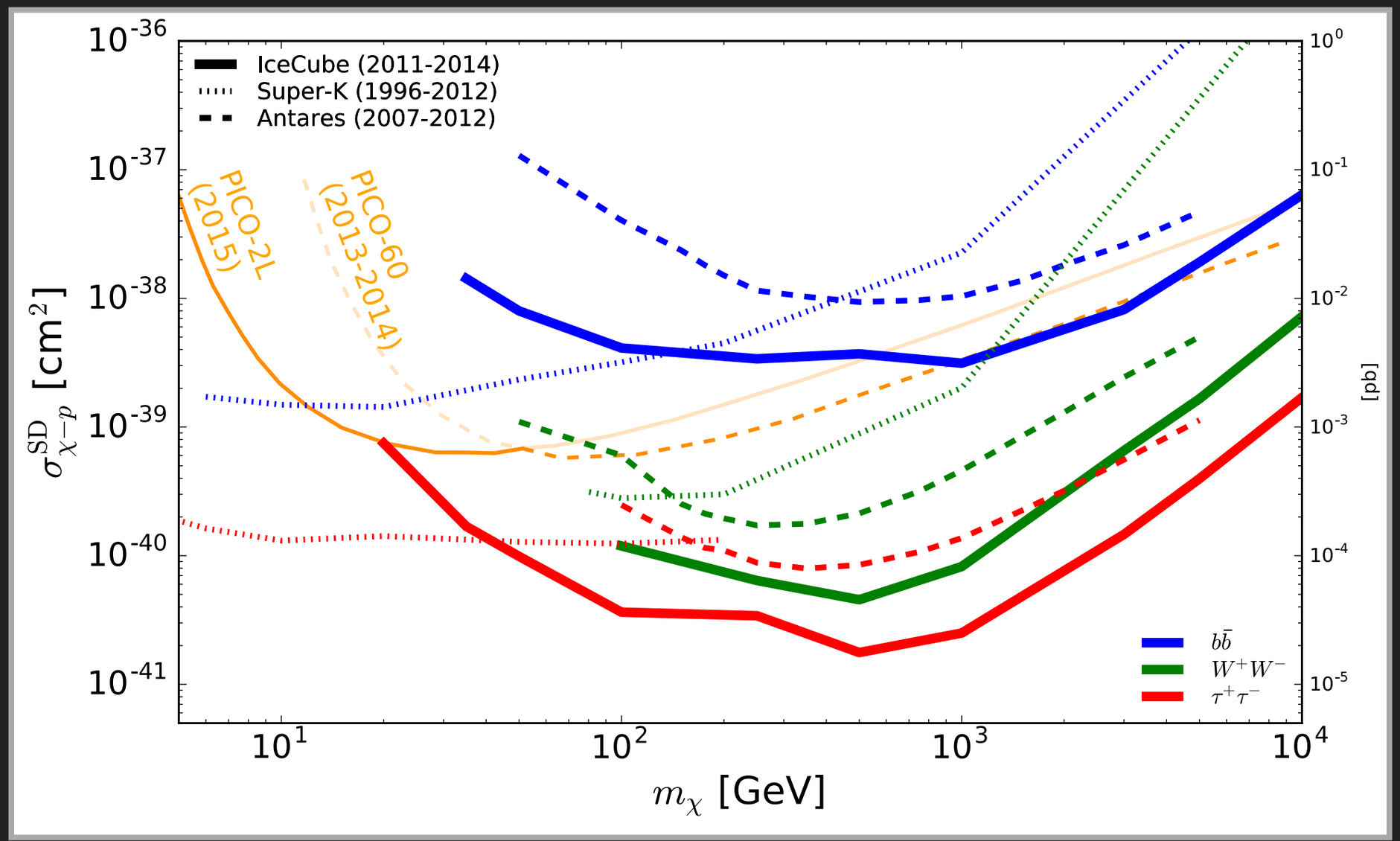


SOLAR WIMP STUDIES

- New results using the finished IceCube with 86 strings
- Results published:
  EPJC **77** 146 (2017) **[arXiv:1612.05949]**
- 3 years of data: 532 days of livetime
- Two independent analyses focusing on high and low dark matter mass
- **No excess** above the expected background

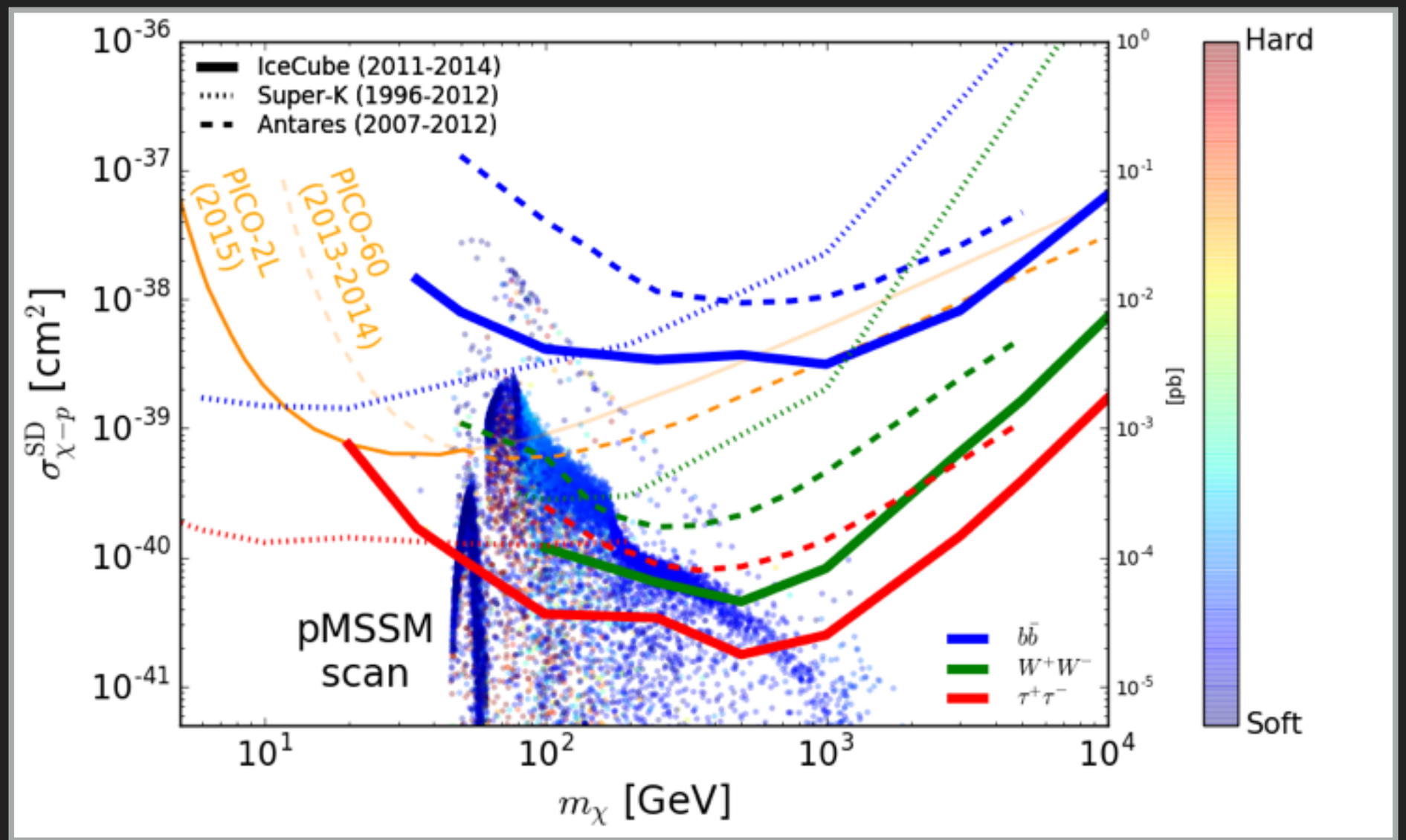
SOLAR WIMP STUDIES

- Presents very competitive bounds on the spin-dependent nucleon-dark matter interaction cross-section



SOLAR WIMP STUDIES

- pMSSM model scans, indicating the fraction of hard and soft final states



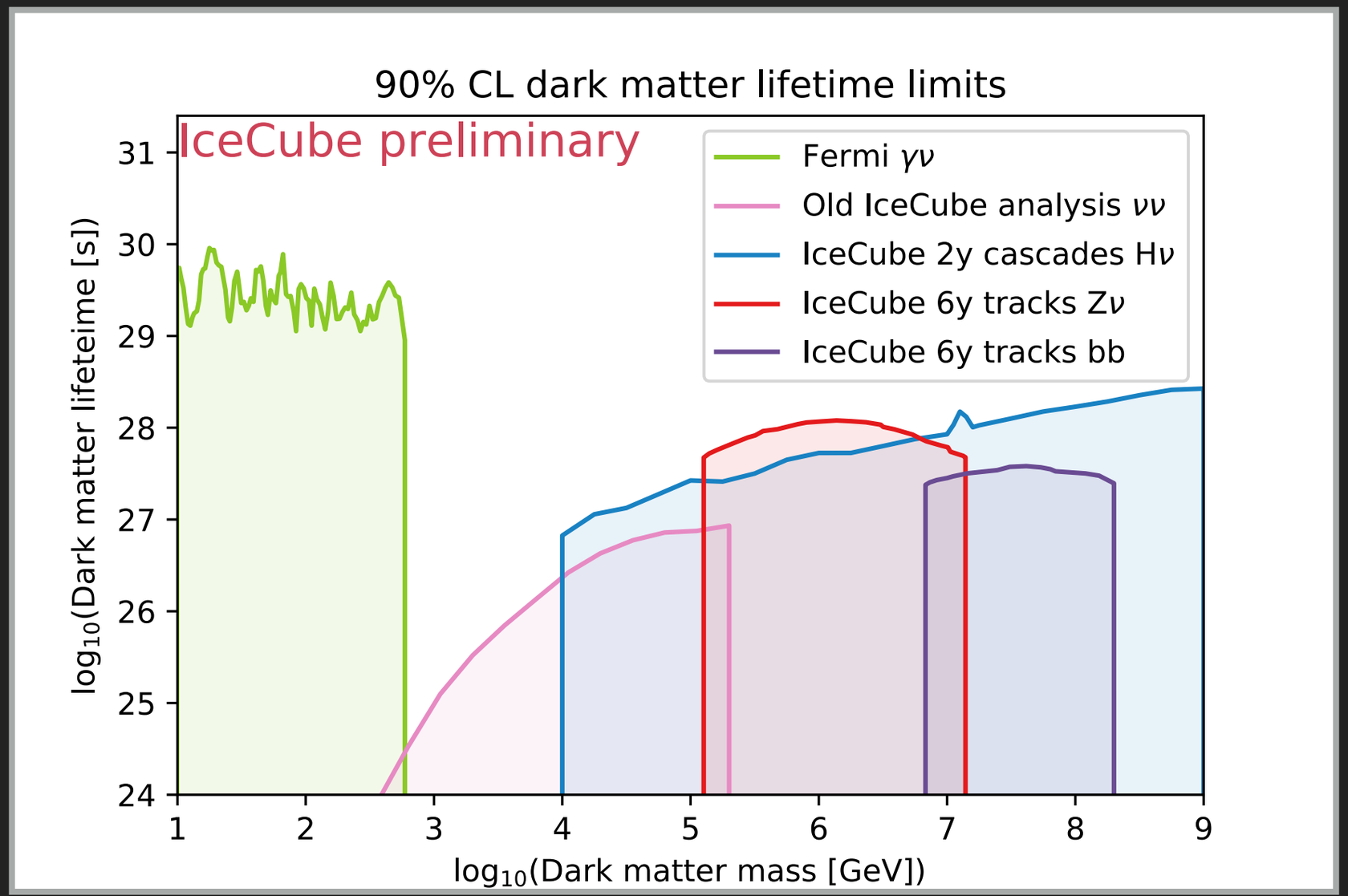
DECAYING DARK MATTER

DECAYING DARK MATTER STUDIES

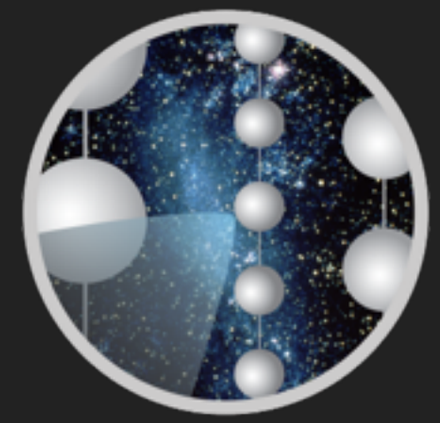
- Dark matter signal: Galactic halo and isotropic extragalactic component
- Background: Atmospheric muons/neutrinos and astrophysical neutrinos
- Analysis fit: Dark matter **mass/lifetime**, isotropic astrophysical **flux/index**
- **Two independent analyses** using event selections designed for unfolding the neutrino spectrum:
  - 1) Using dataset with 6 years of northern hemisphere **tracks**
  - 2) Using dataset with 2 years of full sky **cascades**
- Focusing on the Hv- or Zv-channel which has a significant peak in energy from the neutrino line spectrum
- **No excess** above the expected background

EXPERIMENTAL LIMITS ON DECAYING DARK MATTER

- Adding limits on dark matter lifetime for dark matter masses above 10 TeV for high mass dark matter



SUMMARY



- No observation of a neutrino signal in IceCube compatible with dark matter annihilation
- More sensitive analyses and longer reach in dark matter masses provides very competitive limits on the annihilation cross section
- IceCube is less sensitive to the exact distribution of dark matter in the galactic halo.
- Solar dark matter searches result in world strongest bound on the spin-dependent dark matter-nucleon interaction cross section

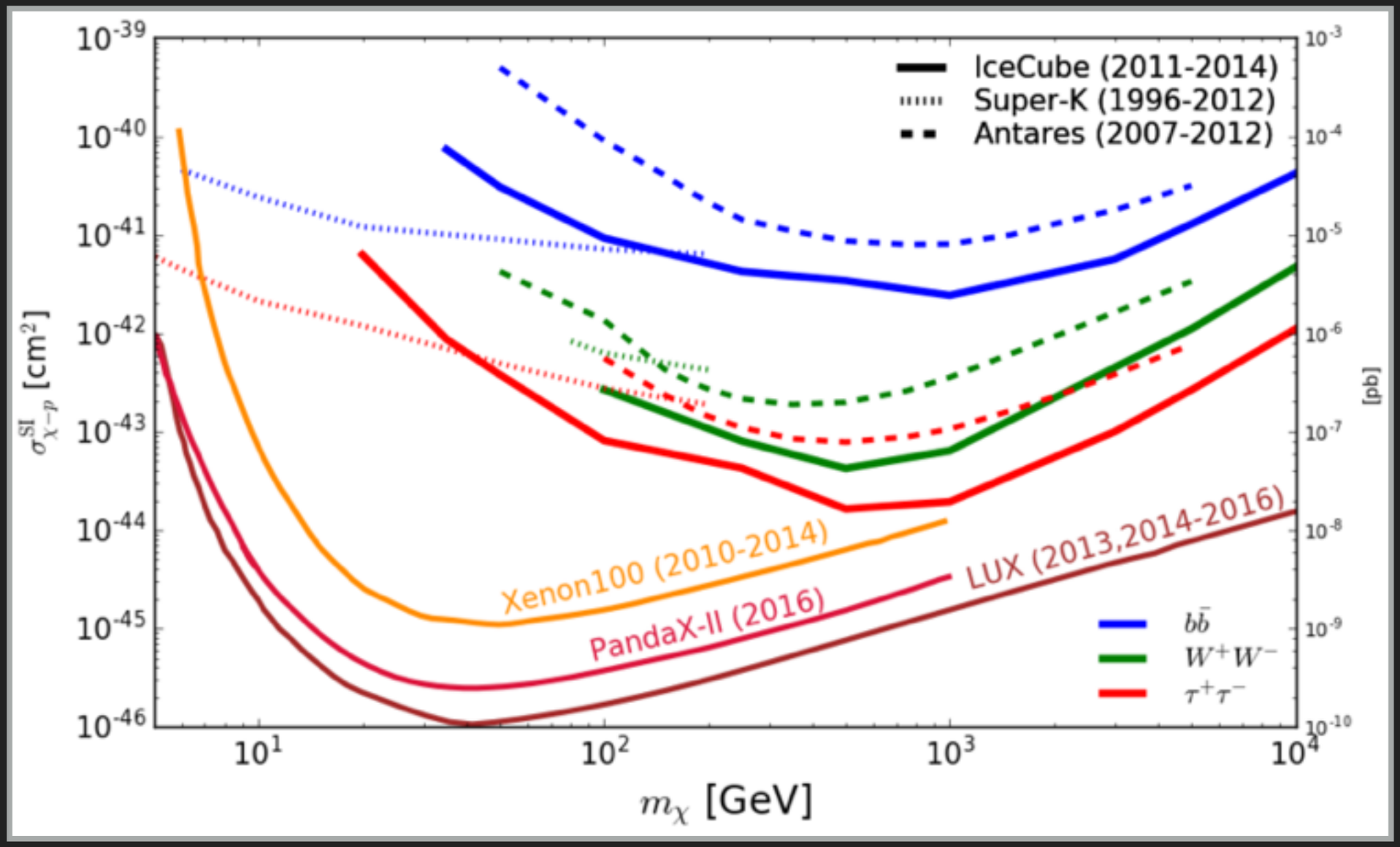
THANKS FOR YOUR ATTENTION!

IceCube

UNIVERSITY OF COPENHAGEN

SOLAR WIMP STUDIES

- Spin-independent dm-nucleon cross section



DECAYING DARK MATTER

- Significant excess of high energy neutrinos above backgrounds
- Used to look for decaying heavy dark matter